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Wojcik et al.

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(54) **TILED DIGITAL RADIOGRAPHY
DETECTORS FOR LONG-LENGTH
IMAGING**

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17, 2014.

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A61B 6/00 (2006.01)

(52) **U.S. Cl.**
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(2013.01); **A61B 6/4411** (2013.01); **A61B**
6/4405 (2013.01); **A61B 6/56** (2013.01)

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G01T 1/2018; G01T 1/2012; G01T
1/2006; G01T 1/20; G01T 1/24
USPC 378/189, 190; 250/586, 332, 208.2,
250/208.1, 581, 370.08
See application file for complete search history.

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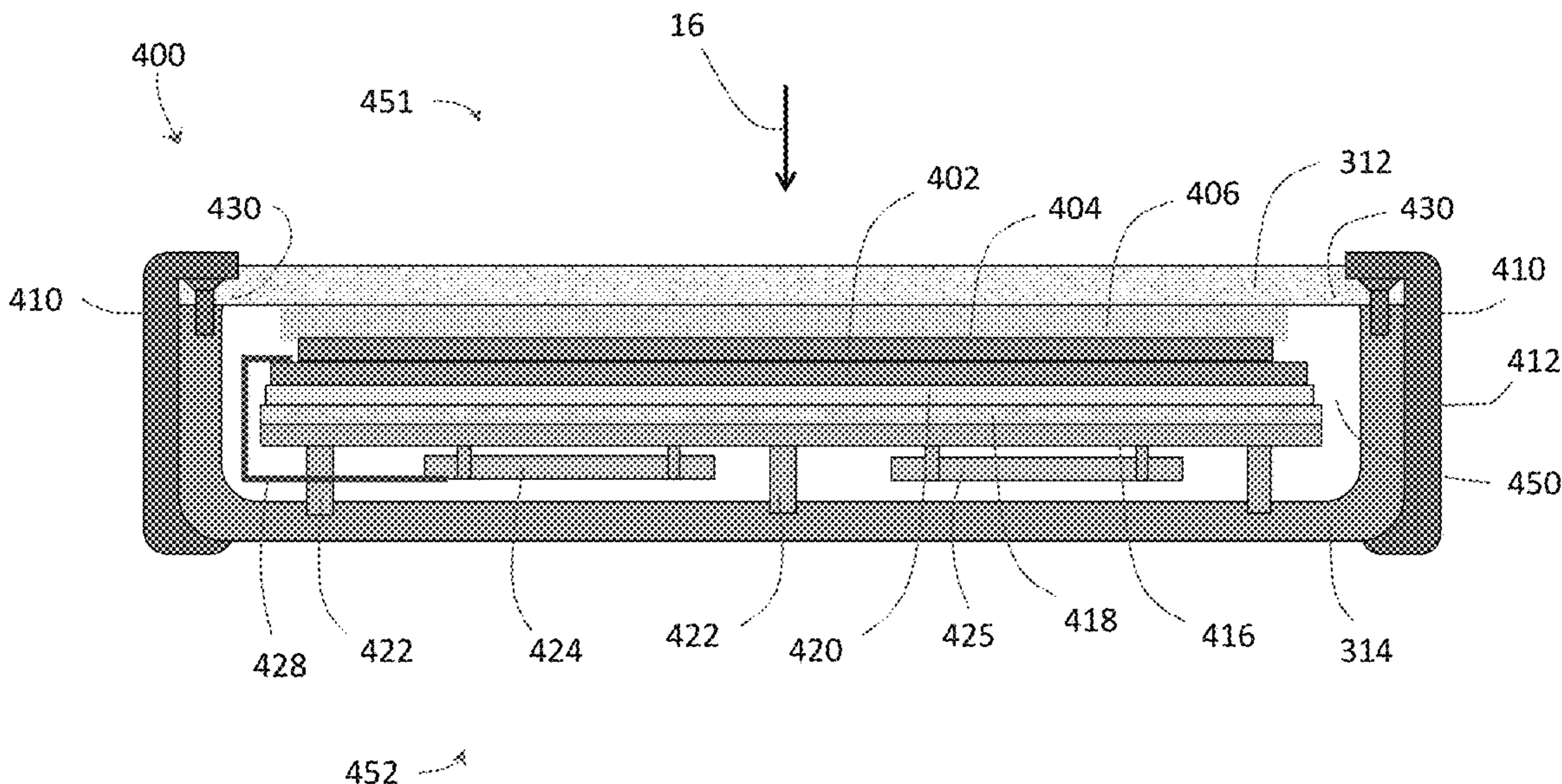
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Primary Examiner — Don Wong

(57) **ABSTRACT**

A digital radiographic detector having a radiolucent cover and housing at one or more edges of the detector allows radiographic imaging using multiple detector arrangements with overlapping edges that do not obstruct radiographic images captured thereby.

19 Claims, 12 Drawing Sheets



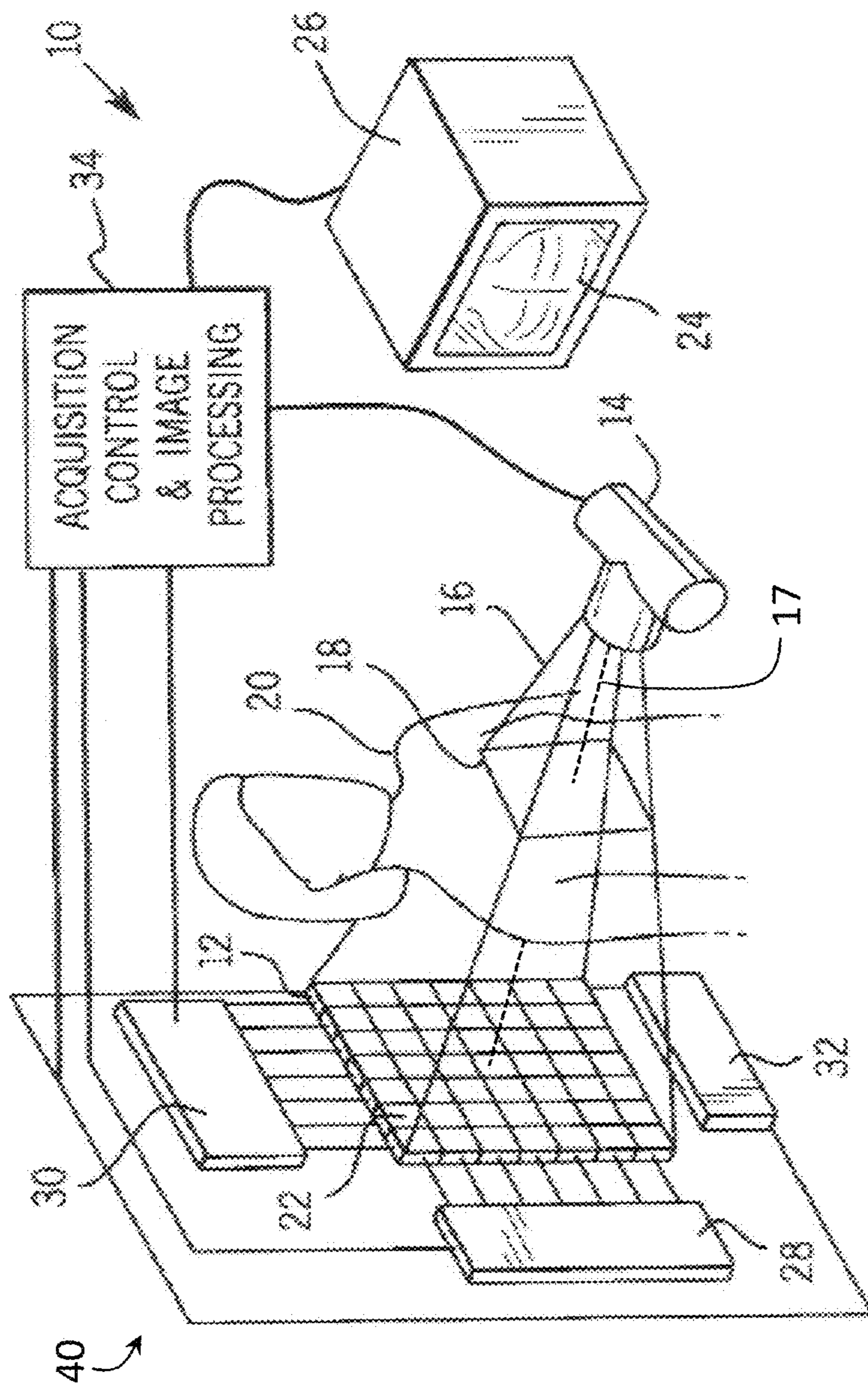


FIG. 1

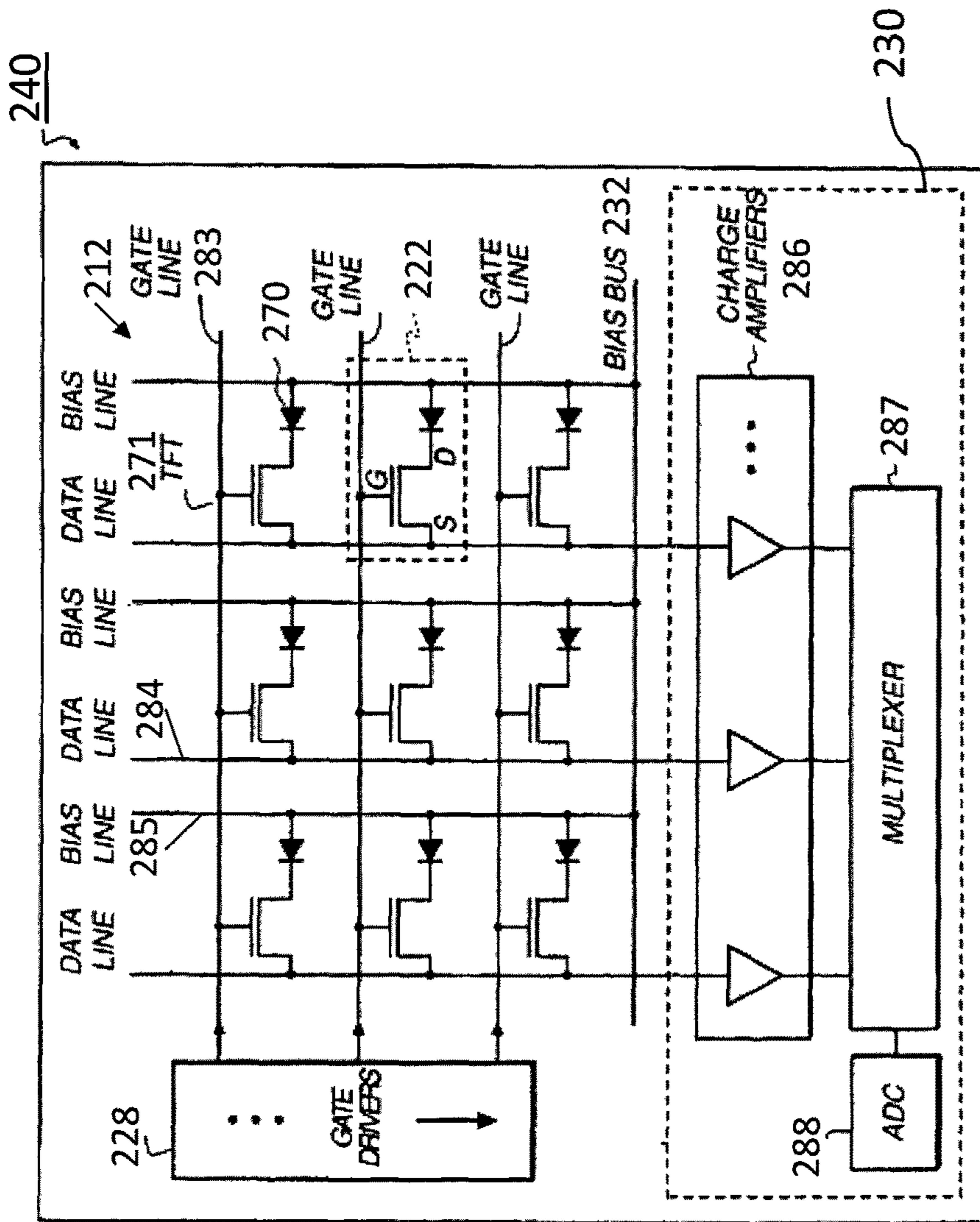


FIG. 2

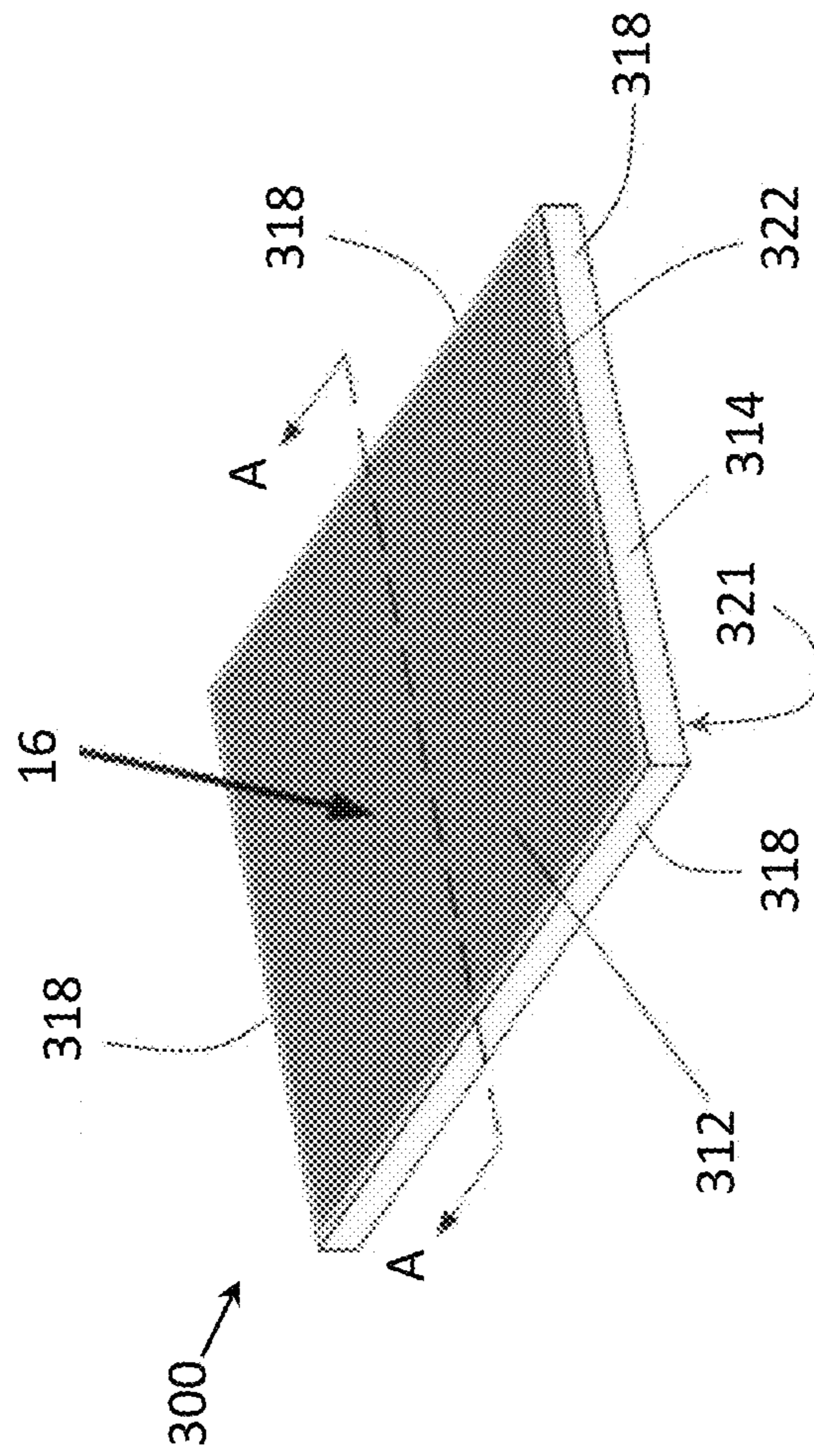


FIG. 3

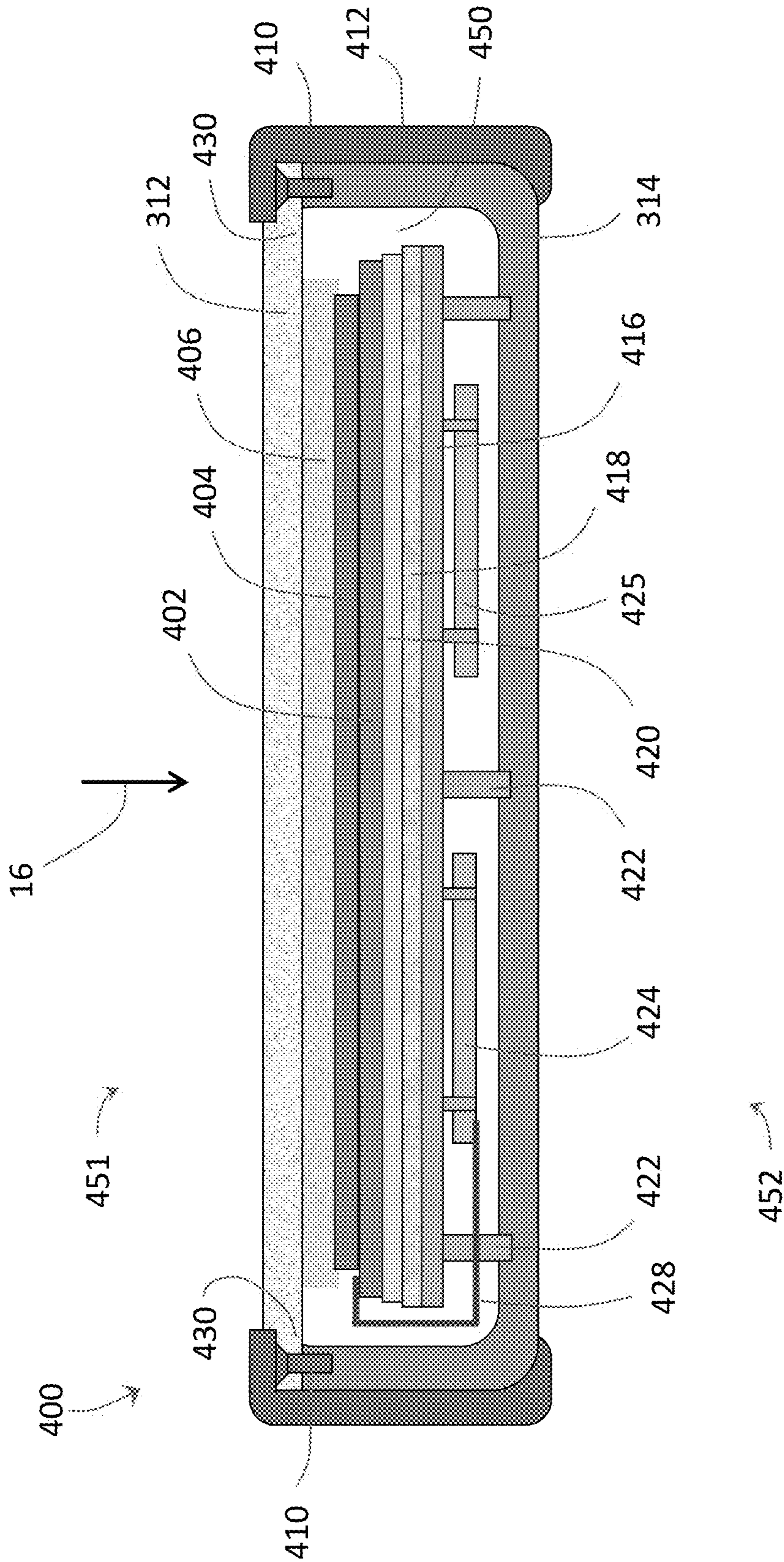
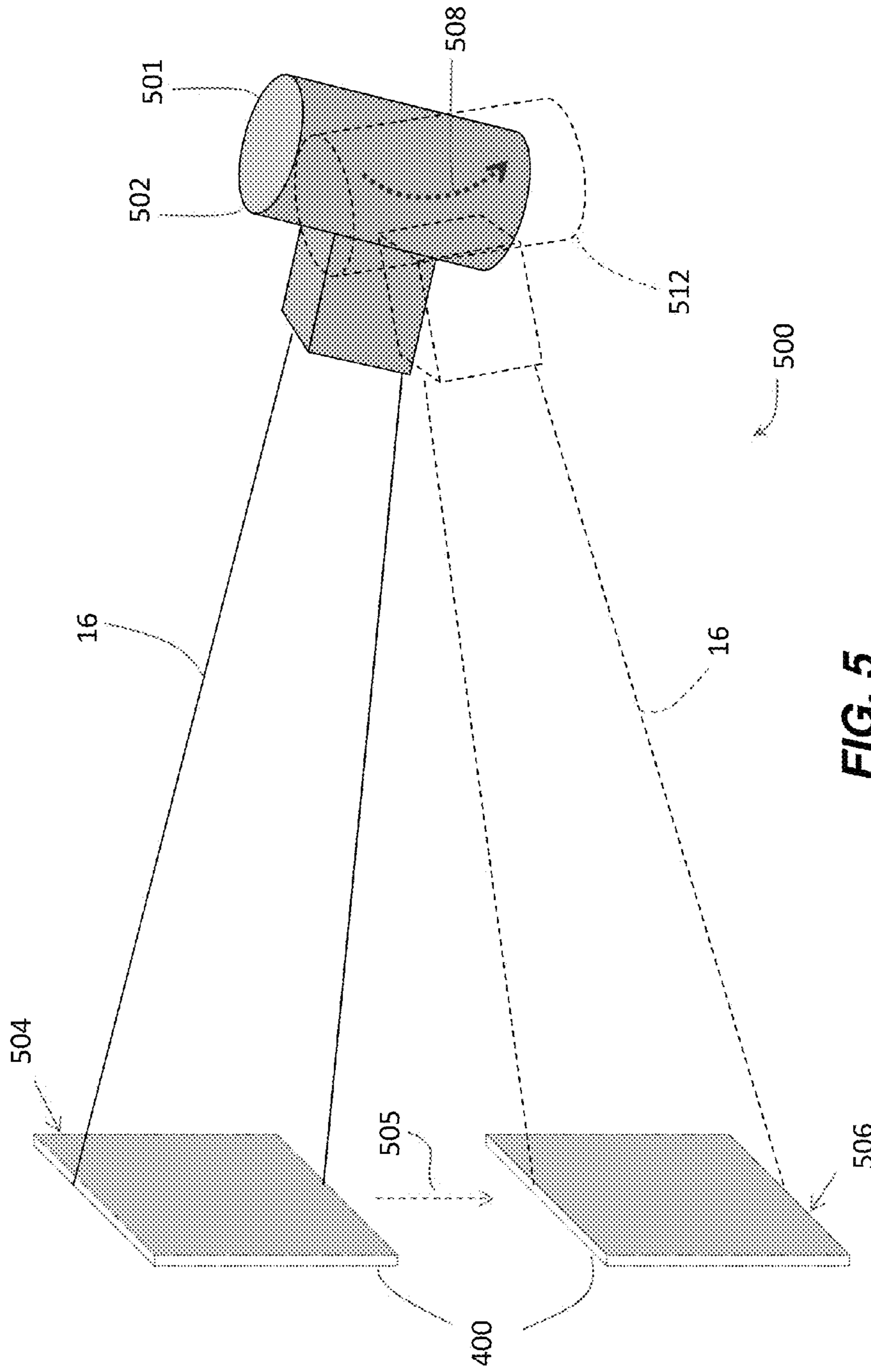


FIG. 4



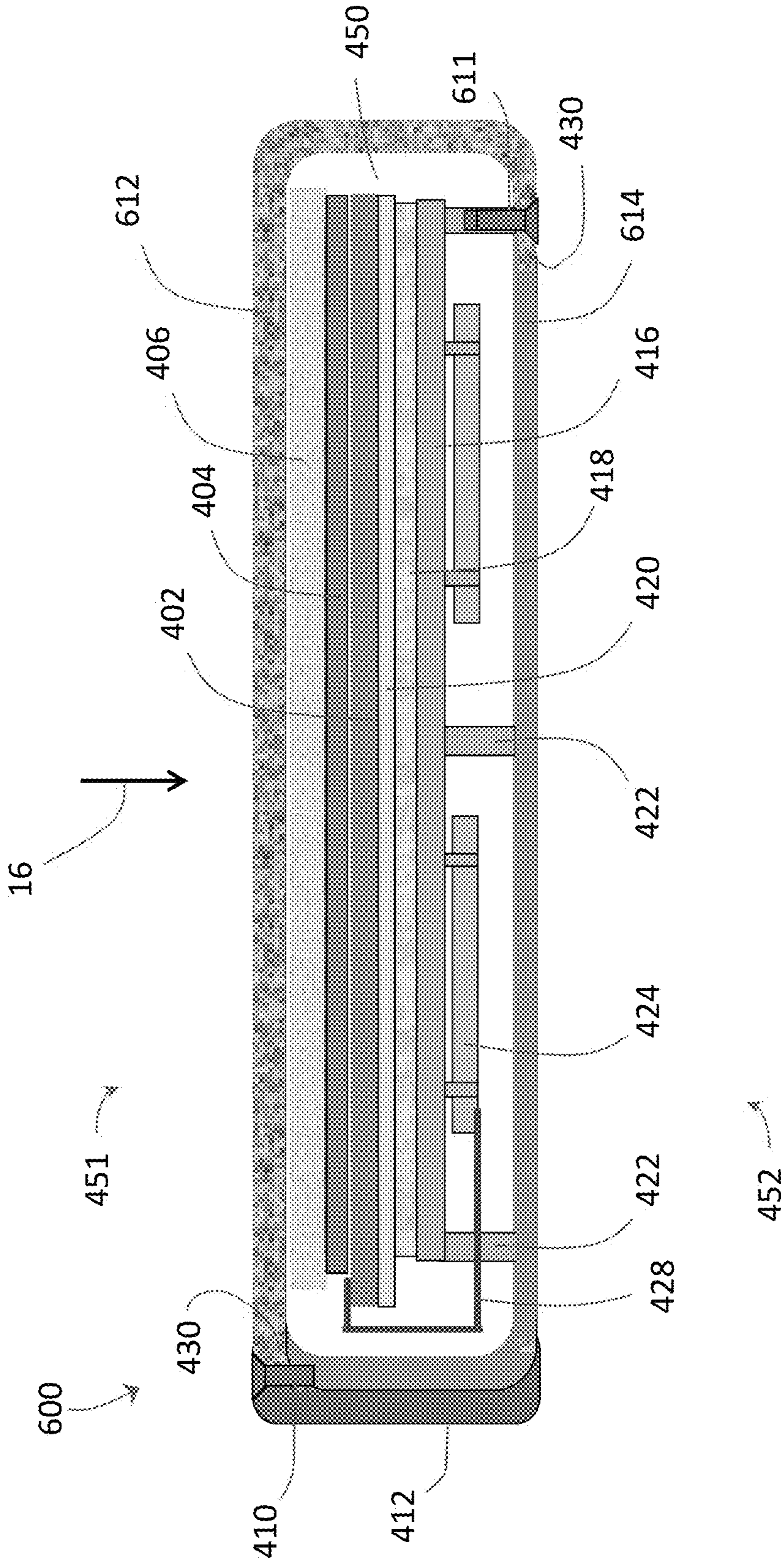


FIG. 6

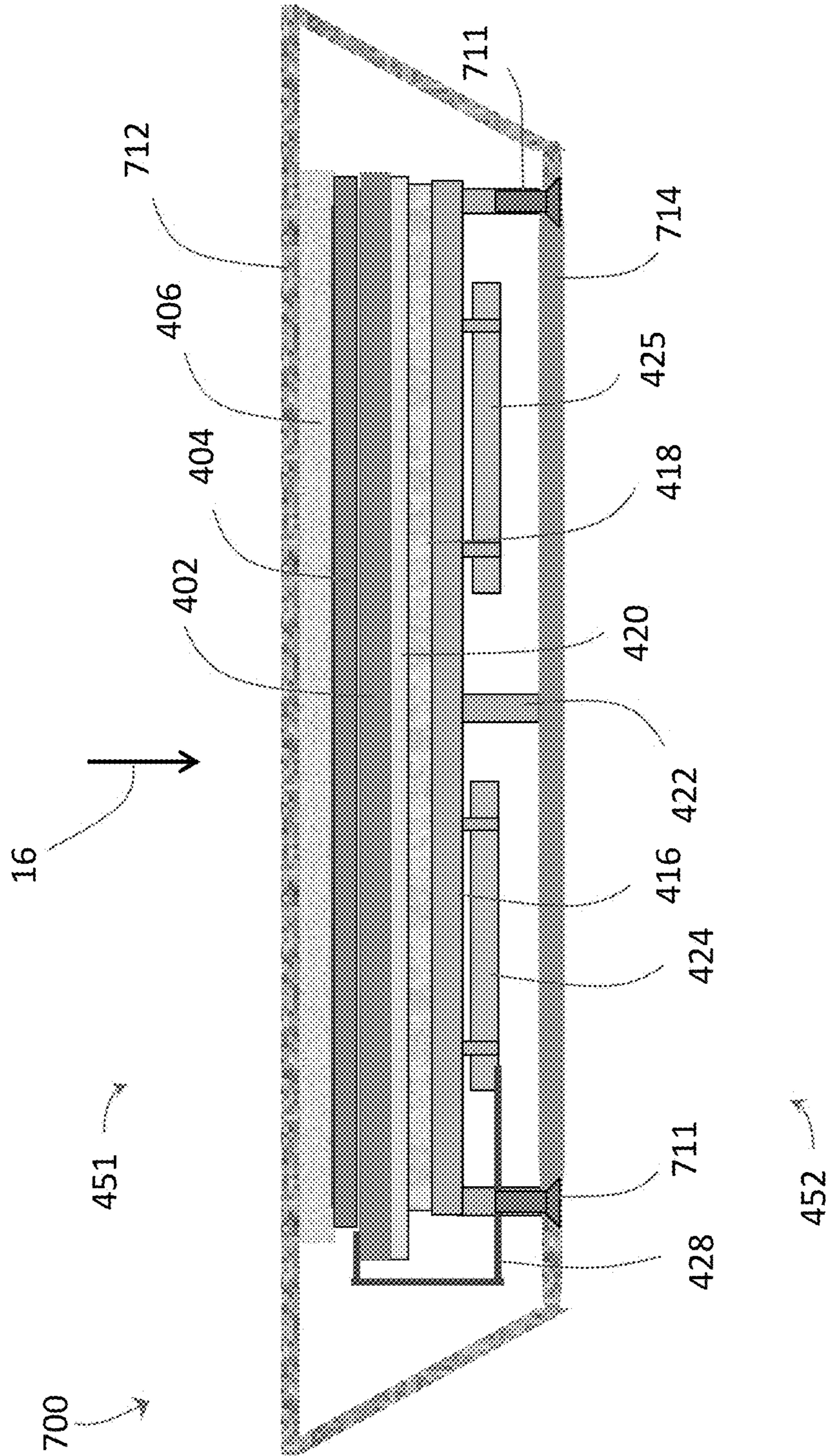


FIG. 7

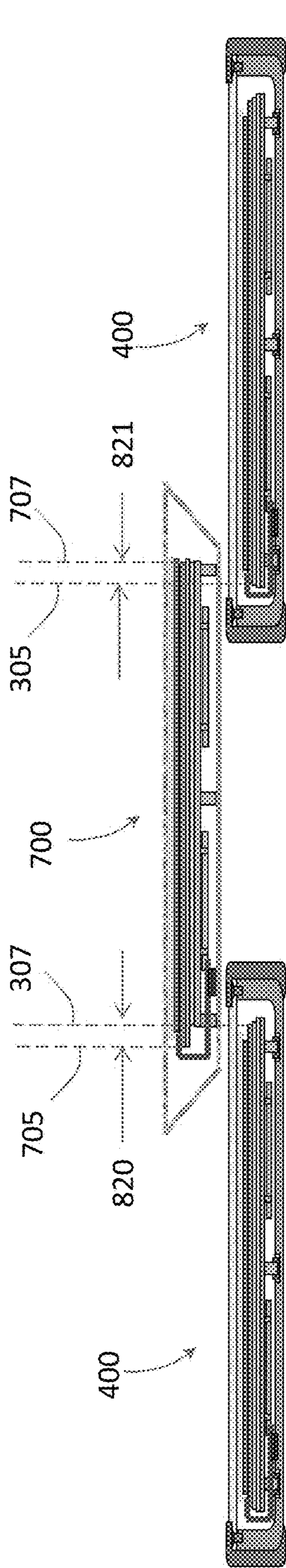


FIG. 8

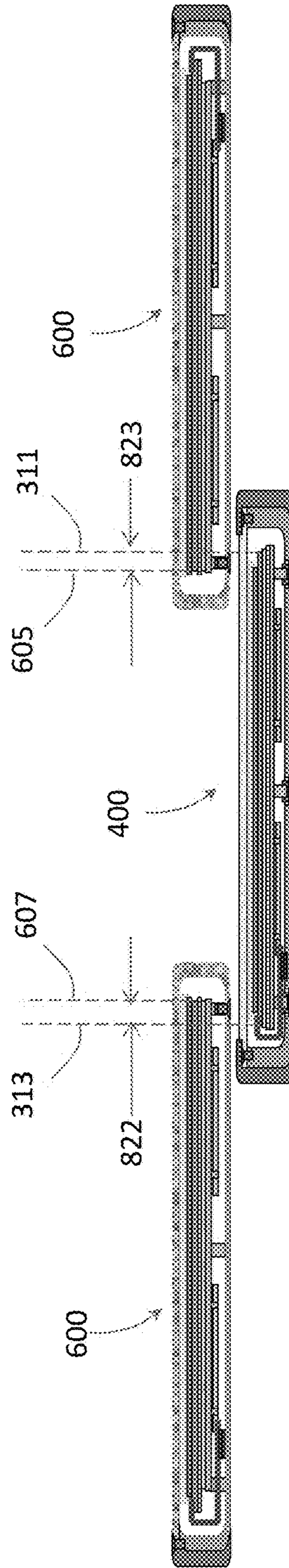


FIG. 9

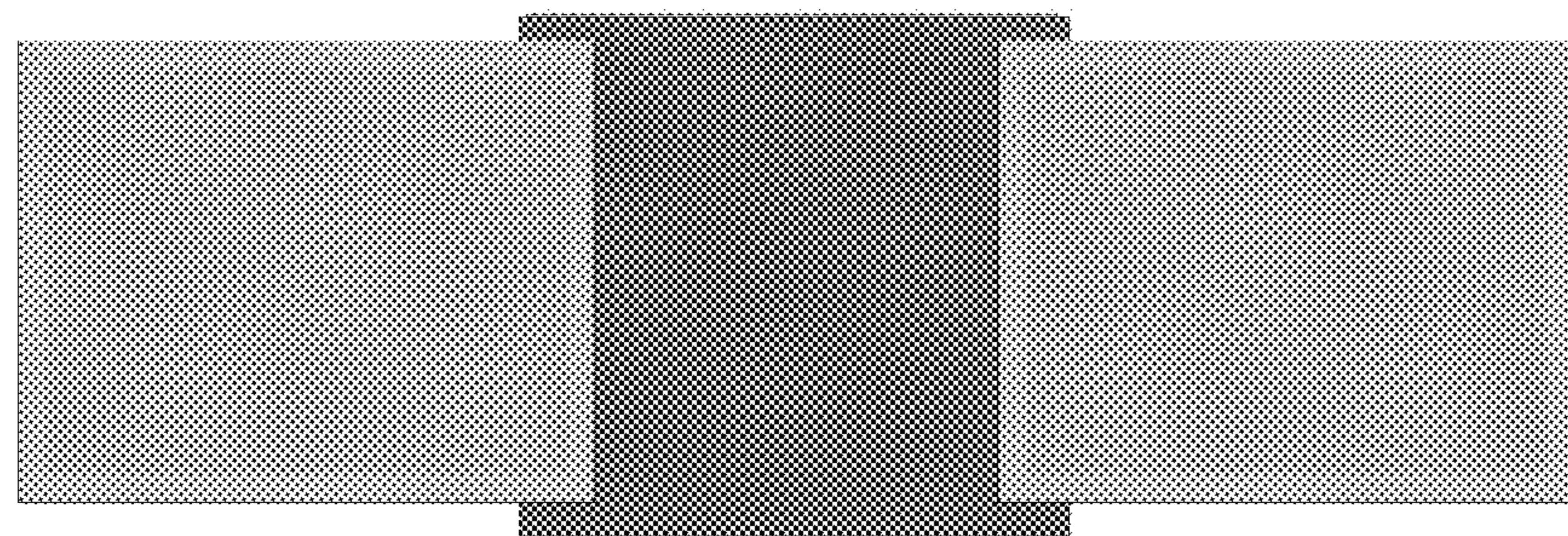


FIG. 11

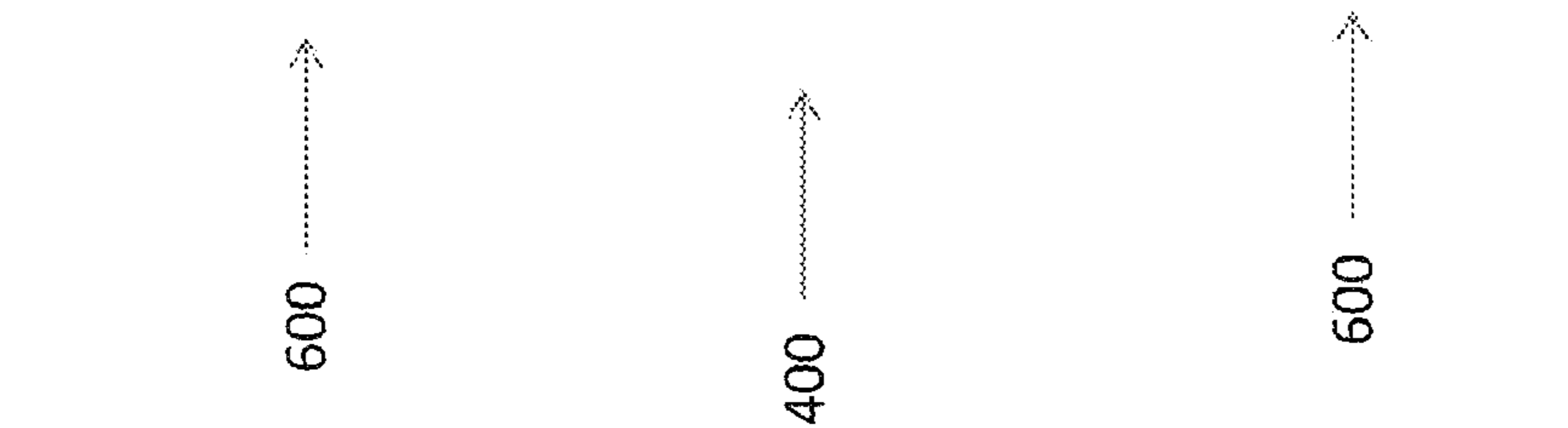


FIG. 10

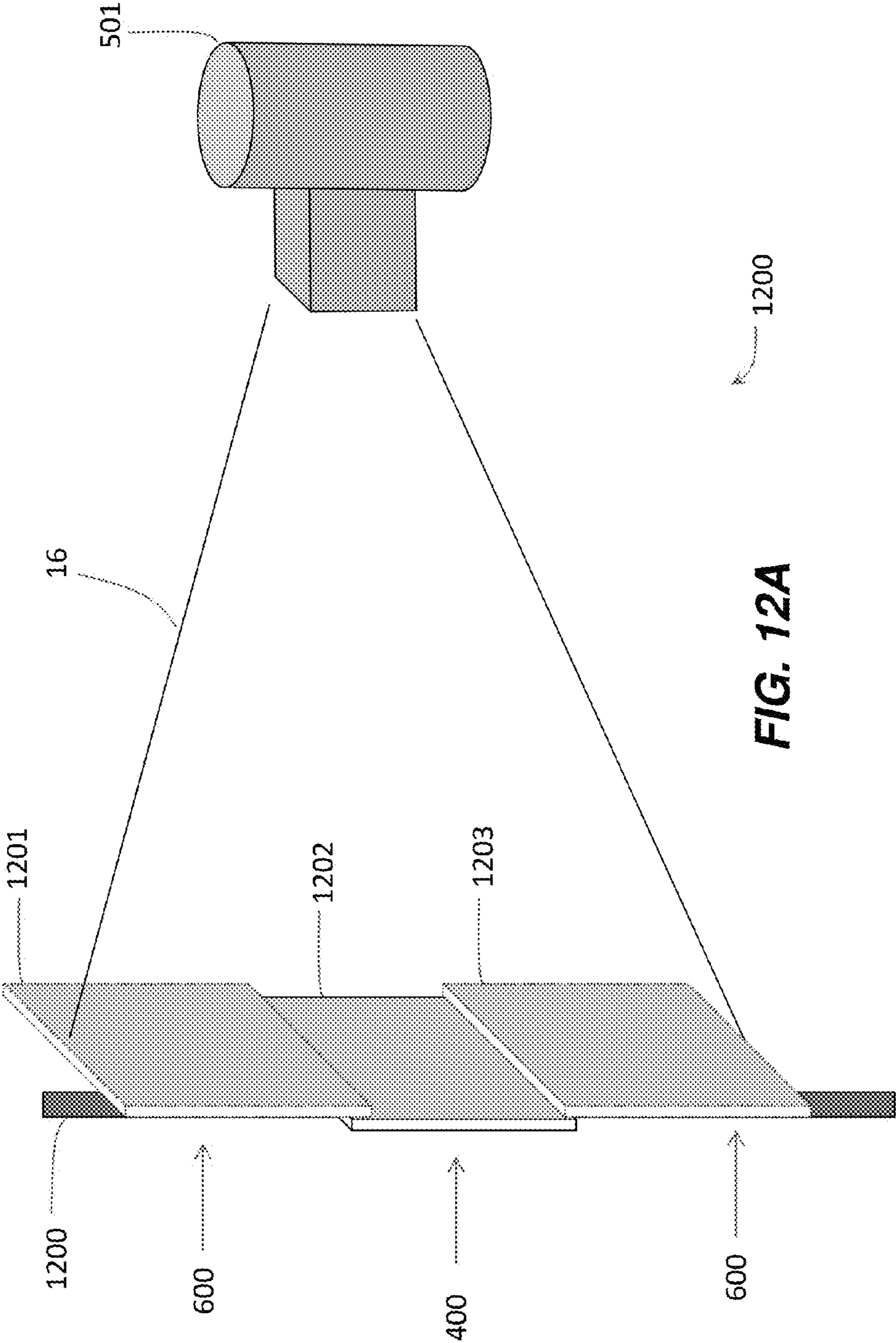


FIG. 12A

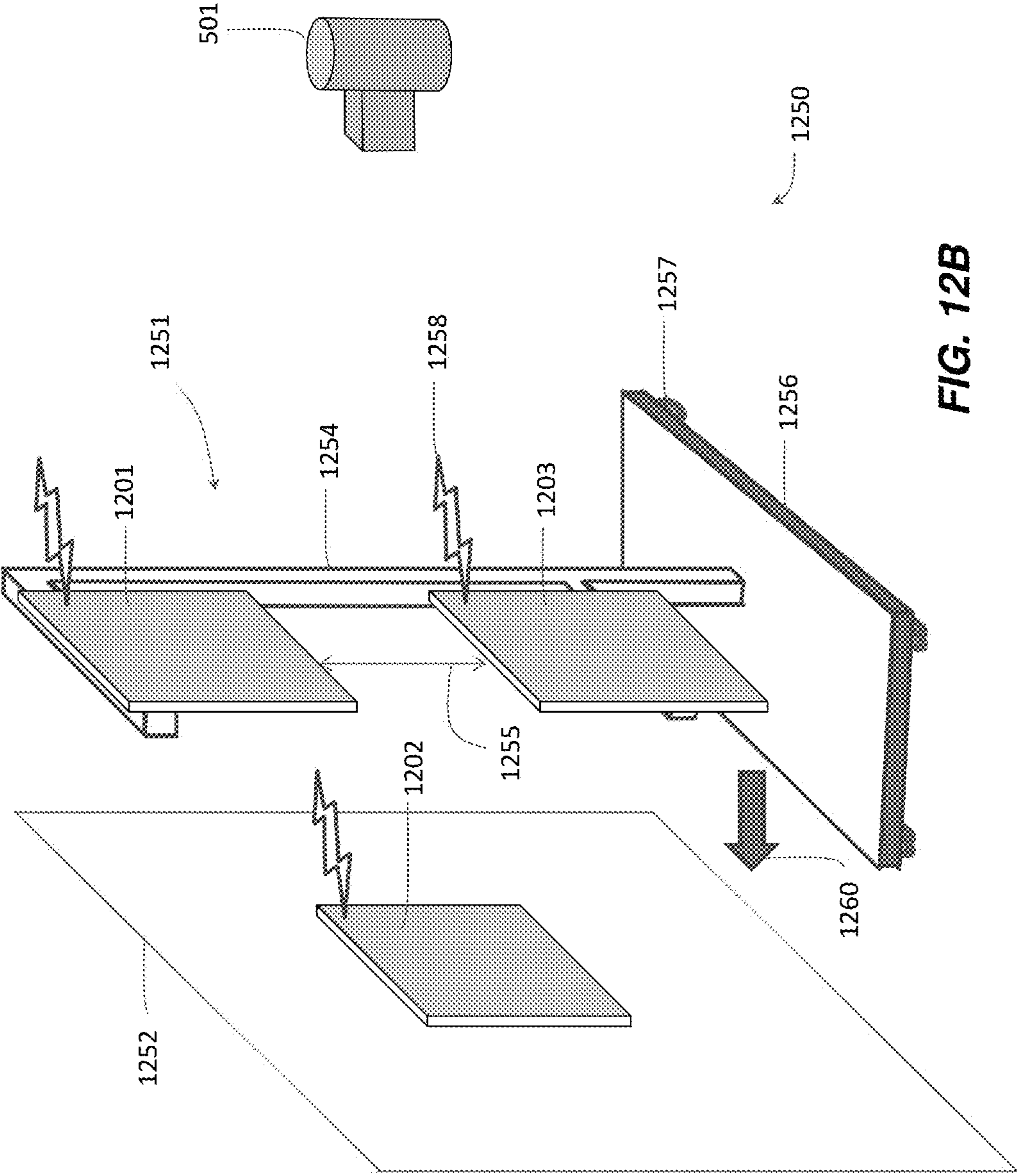
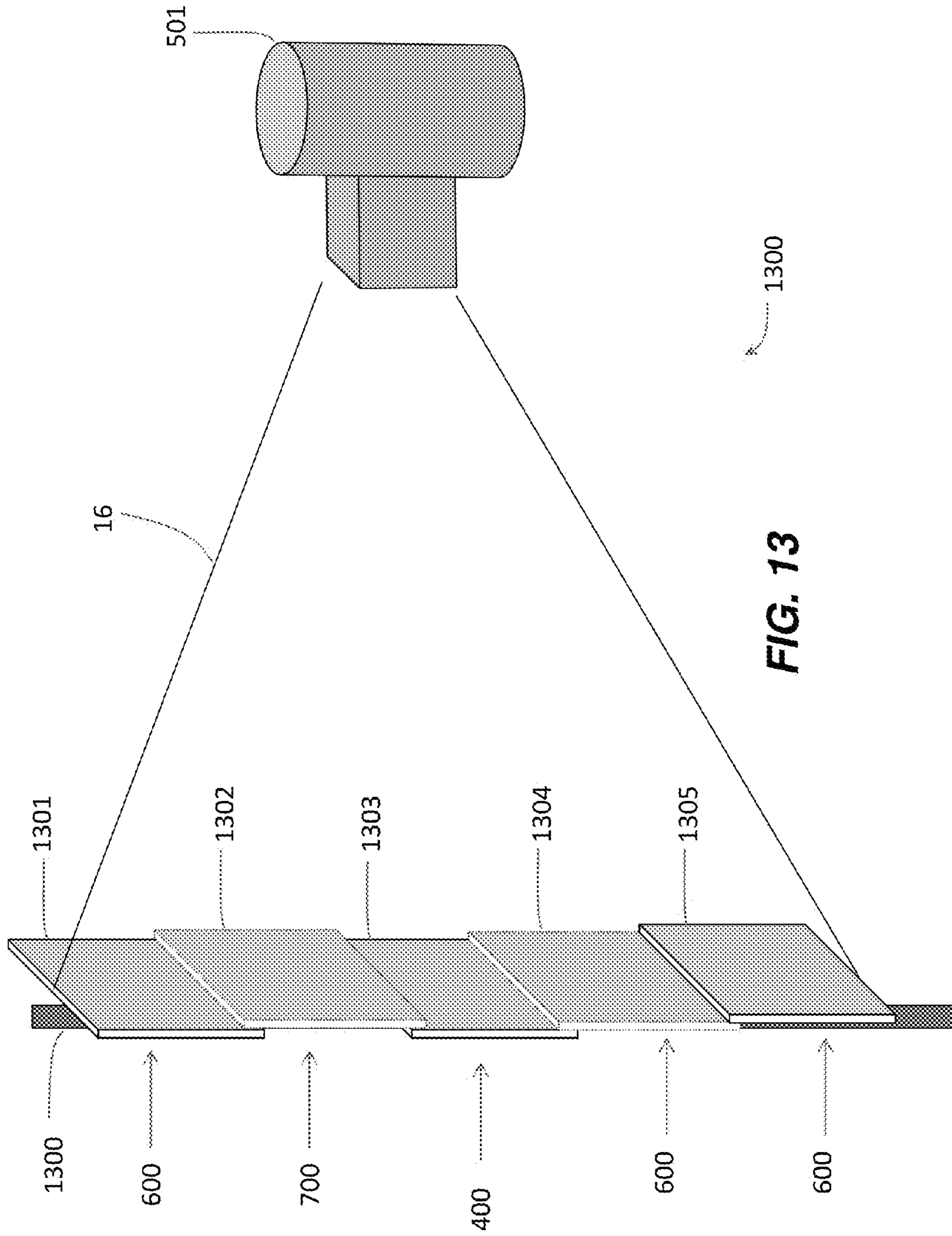


FIG. 12B



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TILED DIGITAL RADIOGRAPHY DETECTORS FOR LONG-LENGTH IMAGING

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Patent Application Ser. No. 62/080,454, filed Nov. 17, 2014, in the name of Wojcik et al., and entitled TILED DIGITAL RADIOGRA-
PHY DETECTORS FOR LONG-LENGTH IMAGING.

BACKGROUND OF THE INVENTION

The subject matter disclosed herein relates to digital radiography (DR) imaging, in particular, to long-length imaging that requires multiple DR detectors.

Special cassettes and films of extended length are sometimes used when imaging a long segment of a subject, such as a human body, with an analog screen-film technique. An x-ray source and the cassette are both centered to the subject to be examined and an x-ray collimator is adjusted to cover the imaging area, whereby a single x-ray exposure is performed. Flat-panel DR detectors are usually limited to 43 cm in length. For long-length imaging applications this would require separate exposures to be taken at different regions of the subject. In order to create a large, single composite image for diagnosis, the individually captured images of the subject need to be stitched together using digital computer-implemented reconstruction techniques.

Two primary approaches are available to acquire long-length imaging exams with flat-panel detectors. In both methods, the detector moves from one imaging position to the next behind the subject. In one known embodiment, the x-ray energy source moves (rotates or tilts) in order to track and expose the detector. In this x-ray source tilting method, the central x-ray pointing direction varies from one exposure position to the next to deliver the x-rays to the detector. In another known embodiment, the x-ray source focal spot position is not stationary, but translates synchronously with the DR detector parallel to the detector's axis of travel.

There are advantages to both embodiments. For example, the tilt method is free of parallax artifacts inherent in the x-ray source translation method. Because of parallax distortion, the geometric integrity of the subject's features in the stitched image may be degraded, particularly in the stitch overlap regions. Automatic image stitching can be achieved with high geometric accuracy such as provided by the Carestream DR DirectView Long-Length Imaging System. A high-precision hardware encoder reports the exact detector travel distance between exposures. In a direction transverse to the detector motion axis, software automatically analyzes the subject's features in the overlap regions to find the best alignment between any two adjacent images. The total stitch error has been demonstrated to be small under stringent exposure conditions.

Automatic exposure control can be used during the long-length imaging exams in order to apply just the right amount of exposure to each region of the subject for image quality. Software may also automatically adjust exposure discrepancies and compensate for the latitude differences, therefore providing optimized image presentation for each image. The image-processing reconstruction algorithm stitches together the individually optimized, display-presentation-ready images to create a smooth and seamless composite single image for diagnosis. The seam line between any two images may be blended without any visible artifacts during this

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digital process. Such imaging software should be able to adjust and fine-tune stitch positions to compensate for movement of the subject during the exam to avoid exposure retakes. In all of the examples just described, it would be advantageous if multiple DR detectors could be used to simultaneously capture a composite radiographic image of a subject in a single exposure.

The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE INVENTION

A digital radiographic detector having a radiolucent cover and housing at one or more edges of the detector allows radiographic imaging using multiple detector arrangements with overlapping edges that do not obstruct radiographic images captured thereby. An advantage that may be realized in the practice of some disclosed embodiments of multiple DR detector systems is that the images are simultaneously exposed and potential movement of the subject during an imaging exam is eliminated, which results in improved long-length image reconstruction and reduced radiation exposure for a subject.

In one embodiment, a digital radiographic detector comprises a multilayer imaging structure with a substantially planar first side having a surface area defined by a plurality of edges. A rigid, radio-opaque housing portion substantially encloses the multilayer structure and surrounds one or more edges of the multilayer structure. A rigid, radiolucent housing portion is attached to the radio-opaque housing portion and surrounds one or more of the edges of the multilayer structure.

In another embodiment, a digital radiography detector comprises a multilayer structure. The multilayer structure includes a substantially planar first side having a surface area defined by a plurality of edges. An imaging device layer is used to receive light energy. A scintillator layer is adjacent the device layer and is used to convert radiographic energy to the light energy. A radiolucent layer covers the scintillator layer, and a rigid, radio-opaque housing substantially encloses the multilayer structure and surrounds one or more edges of the multilayer structure. A rigid, radiolucent housing surrounds one or more edges of the multilayer structure.

In another embodiment, a long-length imaging system comprises three or more digital radiographic detectors. A first detector comprises a multilayer structure with a substantially planar first side having a surface area defined by a plurality of edges. A device layer comprising a plurality of photosensors absorb light energy and a scintillator layer adjacent the device layer converts radiographic energy to the light energy. A radiolucent layer covers the scintillator layer and a rigid, radio-opaque housing substantially encloses the multilayer structure and surrounds one or more edges of the multilayer structure. A rigid, radiolucent housing surrounds one or more edges of the multilayer structure. Second and third detectors are disposed behind the first detector, in relation to a radiographic energy source aimed at the at least three detectors. Two of the edges of the first detectors overlap one edge of the second and third detectors.

In another embodiment, a long-length imaging system comprises three or more digital radiographic detectors. First and second detectors each comprise a multilayer structure with a substantially planar first side having a surface area defined by a plurality of edges. A device layer receives light energy, and a scintillator layer adjacent the device layer converts radiographic energy to the light energy. A radiolu-

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cent layer covers the scintillator layer, and a rigid, radio-opaque housing encloses the multilayer structure and surrounds one or more edges of the multilayer structure. A rigid, radiolucent housing portion surrounds one or more of the edges of the multilayer structure, and a third detector behind the first and second detectors, is overlapped by each of the first and second detectors.

This brief description of the invention is intended only to provide a brief overview of subject matter disclosed herein according to one or more illustrative embodiments, and does not serve as a guide to interpreting the claims or to define or limit the scope of the invention, which is defined only by the appended claims. This brief description is provided to introduce an illustrative selection of concepts in a simplified form that are further described below in the detailed description. This brief description is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The claimed subject matter is not limited to implementations that solve any or all disadvantages noted in the background.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features of the invention can be understood, a detailed description of the invention may be had by reference to certain embodiments, some of which are illustrated in the accompanying drawings. It is to be noted, however, that the drawings illustrate only certain embodiments of this invention and are therefore not to be considered limiting of its scope, for the scope of the invention encompasses other equally effective embodiments. For example, the summary descriptions above are not meant to describe individual separate embodiments whose elements are not interchangeable. In fact, many of the elements described as related to a particular embodiment can be used together with, and possibly interchanged with, elements of other described embodiments. Many changes and modifications may be made within the scope of the present invention without departing from the spirit thereof, and the invention includes all such modifications. The drawings below are intended to be drawn neither to any precise scale with respect to relative size, angular relationship, relative position, or timing relationship, nor to any combinational relationship with respect to interchangeability, substitution, or representation of a required implementation. In the drawings, like numerals are used to indicate like parts throughout the various views. Thus, for further understanding of the invention, reference can be made to the following detailed description, read in connection with the drawings in which:

FIG. 1 is a diagram of an exemplary radiographic imaging system;

FIG. 2 is a schematic diagram of an imaging array for an exemplary radiographic detector;

FIG. 3 shows a perspective view of an exemplary portable wireless DR detector;

FIG. 4 is a cross-section of a portion of the exemplary portable wireless DR detector of FIG. 3 along section line A-A;

FIG. 5 is a diagram of an exemplary radiographic imaging system illustrating positioning of the radiographic energy source and the DR detector;

FIG. 6 is a cross-section of a portion of an exemplary portable wireless DR detector according to one embodiment;

FIG. 7 is a cross-section of a portion of an exemplary portable wireless DR detector according to one embodiment;

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FIG. 8 is a cross-section of an exemplary arrangement of multiple DR detectors in a radiographic imaging system according to one embodiment;

FIG. 9 is a cross-section of an exemplary arrangement of multiple DR detectors in a radiographic imaging system according to one embodiment;

FIG. 10 is a top view of an exemplary arrangement of multiple DR detectors in a radiographic imaging system according to the embodiment of FIG. 8;

FIG. 11 is a top view of an exemplary arrangement of multiple DR detectors in a radiographic imaging system according to the embodiment of FIG. 9;

FIG. 12A is a perspective view of an imaging system implementing an arrangement of DR detectors according to one embodiment;

FIG. 12B is a perspective view of an imaging system implementing an arrangement of DR detectors according to one embodiment; and

FIG. 13 is a perspective view of an imaging system implementing an arrangement of DR detectors according to one embodiment.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a perspective view of a digital radiographic (DR) imaging system 10 that includes a generally planar DR detector 40 (shown without a housing for clarity of description), an x-ray source 14 configured to generate radiographic energy (x-ray radiation), and a digital monitor 26 configured to display images captured by the DR detector 40, according to one embodiment. The DR detector 40 may include a two dimensional array 12 of detector cells 22 (photosensors), arranged in electronically addressable rows and columns. The DR detector 40 may be positioned to receive x-rays 16 passing through a subject 20 during a radiographic energy exposure, or radiographic energy pulse, emitted by the x-ray source 14. As shown in FIG. 1, the radiographic imaging system 10 may use an x-ray source 14 that emits collimated x-rays 16, e.g. an x-ray beam, selectively aimed at and passing through a preselected region 18 of the subject 20. The x-ray beam 16 may be attenuated by varying degrees along its plurality of rays according to the internal structure of the subject 20, which attenuated rays are detected by the array 12 of photosensitive detector cells 22. The planar DR detector 40 is positioned, as much as possible, in a perpendicular relation to a substantially central ray 17 of the plurality of rays 16 emitted by the x-ray source 14. The array 12 of individual photosensitive cells (pixels) 22 may be electronically addressed (scanned) by their position according to column and row. As used herein, the terms "column" and "row" refer to the vertical and horizontal arrangement of the photo sensor cells 22 and, for clarity of description, it will be assumed that the rows extend horizontally and the columns extend vertically. However, the orientation of the columns and rows is arbitrary and does not limit the scope of any embodiments disclosed herein. Furthermore, the term "subject" may be illustrated as a human patient in the description of FIG. 1, however, a subject of a DR imaging system, as the term is used herein, may be a human, an animal, an inanimate object, or a portion thereof.

In one exemplary embodiment, the rows of photosensitive cells 22 may be scanned one or more at a time by electronic scanning circuit 28 so that the exposure data from the array 12 may be transmitted to electronic read-out circuit 30. Each photosensitive cell 22 may independently store a charge proportional to an intensity, or energy level, of the attenuated

radiographic radiation, or x-rays, received and absorbed in the cell. Thus, each photosensitive cell, when read-out, provides information defining a pixel of a radiographic image **24**, e.g. a brightness level or an amount of energy absorbed by the pixel, that may be digitally decoded by image processing electronics **34** and transmitted to be displayed by the digital monitor **26** for viewing by a user. An electronic bias circuit **32** is electrically connected to the two-dimensional detector array **12** to provide a bias voltage to each of the photosensitive cells **22**.

Each of the bias circuit **32**, the scanning circuit **28**, and the read-out circuit **30**, may communicate with an acquisition control and image processing unit **34** over a connected cable **33** (wired) or over a wireless transmitter **35**. The DR detector may be equipped to transmit radiographic image data, and to exchange control and other signals, such as preparatory ready signals, over the cable **33** or wirelessly over transmitter **35** with the acquisition control and image processing unit **34**, which may also include an image processing computer system. The acquisition control and image processing unit **34** may include a processor and electronic memory (not shown) to control operations of the DR detector **40** as described herein, including control of circuits **28**, **30**, and **32**, for example, by use of programmed instructions. The acquisition control and image processing unit **34** may also be used to control activation of the x-ray source **14** during a radiographic exposure, controlling an x-ray tube electric current magnitude, and thus the fluence of x-rays in x-ray beam **16**, and/or the x-ray tube voltage, and thus the energy level of the x-rays in x-ray beam **16**.

The acquisition control and image processing unit **34** may transmit image (pixel) data to the monitor **26**, based on the radiographic exposure data received from the array **12** of photosensitive cells **22**. Alternatively, acquisition control and image processing unit **34** can process the image data and store it, or it may store raw unprocessed image data, in local or remotely accessible memory.

With regard to a direct detection embodiment of DR detector **40**, the photosensitive cells **22** may each include a sensing element sensitive to x-rays, i.e. it absorbs x-rays and generates an amount of charge carriers in proportion to a magnitude of the absorbed x-ray energy. A switching element may be configured to be selectively activated to read out the charge level of a corresponding x-ray sensing element. With regard to an indirect detection embodiment of DR detector **40**, photosensitive cells **22** may each include a sensing element sensitive to light rays in the visible spectrum, i.e. it absorbs light rays and generates an amount of charge carriers in proportion to a magnitude of the absorbed light energy, and a switching element that is selectively activated to read the charge level of the corresponding sensing element. A scintillator, or wavelength converter, is disposed over the light sensitive sensing elements to convert incident x-ray radiographic energy to visible light energy. Thus, in the embodiments disclosed herein, it should be noted that the DR detector **40** (or DR detector **300** in FIG. **3** or DR detector **400** in FIG. **4**) may include an indirect or direct type of DR detector.

Examples of sensing elements used in sensing array **12** include various types of photoelectric conversion devices (e.g., photosensors) such as photodiodes (P-N or PIN diodes), photo-capacitors (MIS), photo-transistors or photoconductors. Examples of switching elements used for signal read-out include MOS transistors, bipolar transistors and other p-n junction components.

FIG. **2** is a schematic diagram **240** of a portion of a two-dimensional array **12** for a DR detector **40**. The array of

photosensor cells **212**, whose operation may be consistent with the photosensor array **12** described above, may include a number of hydrogenated amorphous silicon (a-Si:H) n-i-p photodiodes **270** and thin film transistors (TFTs) **271** formed as field effect transistors (FETs) each having gate (G), source (S), and drain (D) terminals. In embodiments of DR detector **40** disclosed herein, such as a multilayer DR detector (**400** of FIG. **4**), the two-dimensional array of photosensor cells **12** may be formed in a device layer that abuts adjacent layers of the DR detector structure. A plurality of gate driver circuits **228** may be electrically connected to a plurality of gate lines **283** which control a voltage applied to the gates of TFTs **271**, a plurality of readout circuits **230** may be electrically connected to data lines **284**, and a plurality of bias lines **285** may be electrically connected to a bias line bus or a variable bias reference voltage line **232** which controls a voltage applied to the photodiodes **270**. Charge amplifiers **286** may be electrically connected to the data lines **284** to receive signals therefrom. Outputs from the charge amplifiers **286** may be electrically connected to a multiplexer **287**, such as an analog multiplexer, then to an analog-to-digital converter (ADC) **288**, or they may be directly connected to the ADC, to stream out the digital radiographic image data at desired rates. In one embodiment, the schematic diagram of FIG. **2** may represent a portion of a DR detector **40** such as an a-Si:H based indirect flat panel imager as described below with respect to the exemplary embodiments of FIGS. **4**, **6**, and **7**.

Incident x-rays, or x-ray photons, **16** are converted to optical photons, or light rays, by a scintillator, which light rays are subsequently converted to electron-hole pairs, or charges, upon impacting the a-Si:H n-i-p photodiodes **270**. In one embodiment, an exemplary detector cell **222**, which may be equivalently referred to herein as a pixel, may include a photodiode **270** having its anode electrically connected to a bias line **285** and its cathode electrically connected to the drain (D) of TFT **271**. The bias reference voltage line **232** can control a bias voltage of the photodiodes **270** at each of the detector cells **222**. The charge capacity of each of the photodiodes **270** is a function of its bias voltage and its capacitance. In general, a reverse bias voltage, e.g. a negative voltage, may be applied to the bias lines **285** to create an electric field (and hence a depletion region) across the pn junction of each of the photodiodes **270** to enhance its collection efficiency for the charges generated by incident light rays. The image signal represented by the array of photosensor cells **212** may be integrated by the photodiodes while their associated TFTs **271** are held in a non-conducting (off) state, for example, by maintaining the gate lines **283** at a negative voltage via the gate driver circuits **228**. The photosensor cell array **212** may be read out by sequentially switching rows of the TFTs **271** to a conducting (on) state by means of the gate driver circuits **228**. When a row of the pixels **22** is switched to a conducting state, for example by applying a positive voltage to the corresponding gate line **283**, collected charge from the photodiode in those pixels may be transferred along data lines **284** and integrated by the external charge amplifier circuits **286**. The row may then be switched back to a non-conducting state, and the process is repeated for each row until the entire array of photosensor cells **212** has been read out. The integrated signal outputs are transferred from the external charge amplifiers **286** to an analog-to-digital converter (ADC) **288** using a parallel-to-serial converter, such as multiplexer **287**, which together comprise read-out circuit **230**.

This digital image information may be subsequently processed by image processing system 34 to yield a digital image which may then be digitally stored and immediately displayed on monitor 26, or it may be displayed at a later time by accessing the digital electronic memory containing the stored image. The flat panel DR detector 40 having an imaging array as described with reference to FIG. 2 is capable of both single-shot (e.g., static, radiographic) and continuous (e.g., fluoroscopic) image acquisition.

FIG. 3 shows a perspective view of an exemplary prior art generally rectangular, planar, portable wireless DR detector 300 according to an embodiment of DR detector 40 disclosed herein. The DR detector 300 may include a housing portion 314 that surrounds a multilayer structure comprising the photosensor array portion 22 of the DR detector 300. The housing portion 314 of the DR detector 300 may include a continuous, rigid, x-ray opaque material or, as used synonymously herein a radio-opaque material, surrounding an interior volume of the DR detector 300. The housing portion 314 comprises four edges 318, extending between the top side 321 and the bottom side 322, and arranged substantially orthogonally in relation to the top and bottom sides 321, 322. The bottom side 322 may be continuous with the four edges and disposed opposite the top side 321 of the DR detector 300. The top side 321 comprises a top cover 312 attached to the housing portion 314 which, together with the housing portion 314, substantially encloses the multilayer structure in the interior volume of the DR detector 300. The top cover 312 may be attached to the housing 314 to form a seal therebetween, and be made of a material that passes x-rays 16 without significant attenuation thereof, i.e., an x-ray transmissive material or, as used synonymously herein, a radiolucent material, such as carbon fiber and plastic, polymeric, or other plastic based material.

With reference to FIG. 4, there is illustrated in schematic form an exemplary cross-section view along section A-A of the exemplary embodiment of the DR detector 300 (FIG. 3). For spatial reference purposes, one major surface of the DR detector 400 may be referred to as the top side 451 and a second major surface may be referred to as the bottom side 452, as used herein. The embodiment of the DR detector 400 depicted in FIG. 4 may be referred to herein as a "standard" DR detector. The multilayer structure is disposed within the interior volume 450 enclosed by the housing 314 and top cover 312 and may include a substantially planar scintillator layer 404 over the two-dimensional imaging sensor array 12 shown schematically as the device layer 402. The scintillator layer 404 may be directly under (e.g., directly connected to) the substantially planar top cover 312, and the imaging array 402 may be directly under the scintillator 404. Alternatively, a flexible layer 406 may be positioned between the scintillator layer 404 and the top cover 312 as part of the multilayer structure to provide shock absorption. The flexible layer 406 may be selected to provide an amount of flexible support for both the top cover 312 and the scintillator 404, and may comprise a foam rubber type of material. The layers just described comprising the multilayer structure each may generally be formed in a rectangular shape and defined by edges arranged orthogonally and disposed in parallel with an interior side of the edges 318 of the housing 314, as described in reference to FIG. 3.

A substrate layer 420 may be disposed under the imaging array 402, such as a rigid glass layer upon which the array of photosensors 402 is formed, and may comprise another layer of the multilayer structure. Under the substrate layer 420 a radio-opaque shield layer 418 may be used as an x-ray blocking layer to help prevent scattering of x-rays passing

through the substrate layer 420 as well as to block x-rays reflected from other surfaces in the interior volume 450. Readout electronics, including the scanning circuit 28, the read-out circuit 30, and the bias circuit 32 (all of FIG. 1) may be formed co-planar with the imaging array 402 or, as shown, may be disposed below frame support member 416 in the form of integrated circuits electrically connected to printed circuit boards 424. The frame support member 416 is fixed to the housing 314 using frame support beams 422 to provide support for the multilayer structure just described. The imaging array 402 is electrically connected to the integrated circuit readout electronics 424 over a flexible connector 428 which may comprise a plurality of flexible, sealed conductors. X-ray flux may pass through the radiolucent top panel cover 312, in the direction represented by an exemplary x-ray beam 16, and impinge upon scintillator 404 where stimulation by the high-energy x-rays 16, or photons, causes the scintillator 404 to emit lower energy photons as visible light rays which are then received in the photosensors of imaging array 402. The frame support member 416 may securely mount the multilayer structure to the housing 314 and may further operate as a shock absorber by disposing elastic pads (not shown) between the frame support beams 422 and the housing 314. Fasteners 410, such as screws, may be used to fixedly attach the top cover 312 to the housing 314 and create a seal therebetween in the region 430 where they come into contact. In one embodiment, an external bumper 412 may be attached along the edges 318 of the DR detector 400 to provide additional shock-absorption.

FIG. 5 illustrates operation of an embodiment of an imaging system 500 which may be used for long-length radiographic imaging of a stationary subject (not shown) positioned between an x-ray source 501 and DR detector 400. The x-ray radiation source 501 in the first position 502 is aimed at DR detector 400 in position 504 to capture a first radiographic image of the subject. In the embodiment shown in FIG. 5, the x-ray radiation source may be tilted in the direction indicated by arrow 508 to a second position 512 and aimed at DR detector 400 in position 506 to capture a second image of the stationary subject, wherein the first and second images each include an image of a different region of the same subject. In the embodiment of FIG. 5, a single DR detector 400 may be moved in the direction indicated by arrow 505 from the first position 504 to the second position 506 to capture the two images of the subject as just described. In another embodiment, two separate DR detectors 400 may be used, one in each of positions 504 and 506, wherein each DR detector 400 is exposed to one radiographic pulse from the x-ray source 501 firing first and second radiographic energy pulses at positions 502 and 512. In another embodiment, the DR detector 400 may be moved to one or more intermediate positions between positions 504 and 506, with corresponding intermediate tilt positions of the x-ray source 501 between positions 502 and 512 to capture one or more additional radiographic images. In another embodiment, the x-ray source may be attached to a support at a fixed angle such that the x-ray source 501 is not tiltable, rather, the support is configured to move vertically and is used to translate the x-ray source 501 to a position corresponding to the DR detector positions 504 and 506, or to the intermediate positions of the DR detector 400 as just described. Thus, it should be understood that embodiments of imaging system 500 may include various combinations of one or more DR detectors 400, which may be fixed or moveable, together with an x-ray source 501 that may be tiltable and/or vertically translatable. In one embodiment,

the one or more positions of DR detector **400** may overlap, resulting in a plurality of captured radiographic images that may be stitched together into one long-length digital image of the subject using known computer-implemented image reconstruction processing techniques.

FIG. **6** illustrates in schematic form another exemplary cross-section view along section A-A of the exemplary embodiment of the DR detector **300** (FIG. **3**). Several of the components in the DR detector **600** illustrated in FIG. **6** are similar in most respects to the components as described with respect to the DR detector **400** of FIG. **4** and are identified with the same element numerals. The description of those components bearing the same element numerals is not repeated here. The DR detector **600** comprises a housing **614** having a portion made from a radio-opaque material extending along a bottom portion of the DR detector **600** and also continuously forms at least one edge of the housing **614** which, in the perspective of FIG. **6**, is located to the left of the interior volume **450**. In separate embodiments, the radio-opaque portion of the housing **614** may continuously extend long one, two, or three edges of a DR detector **600** having four edges. If the radio-opaque portion of the housing **614** extends along two edges, it may extend along any two adjacent and substantially perpendicular edges or along any pair of opposite substantially parallel edges of the DR detector **600**.

In the exemplary embodiment of FIG. **6**, a portion of the housing **612** is formed from a radiolucent material. This portion of the housing may comprise a continuous extension of the top cover **312** (FIG. **4**) to form a portion of the housing **612** for the DR detector **600** that is transparent to x-ray radiation. In separate embodiments, the radiolucent portion of the housing **612** may continuously extend along one, two, or three edges of a DR detector **600** having four edges. If the radiolucent portion of the housing **612** extends along two edges, it may extend along any two adjacent substantially perpendicular edges or along any pair of opposite substantially parallel edges of the DR detector **600**. In order to fasten the radiolucent portion of the housing **612**, a fastener **611**, similar in material and shape as fastener **410**, may be used in the bottom side of the DR detector to sealingly fasten the radiolucent edge of the housing **612** to the frame support **416** or to a frame support beam **422**. At the edges of the DR detector **600** where the radio-opaque housing **614** extends along the edges toward the top side **451**, the fastener **410** may be used as described herein to sealingly fasten it to the radiolucent portion of the housing **612**. The fastener **611** is positioned in the bottom side **452** to minimize or eliminate placement of any DR detector components that are not radiolucent above, or beyond an edge of, the imaging layer **402** closest to a radiolucent edge of the DR detector **600**. This helps to prevent artifacts appearing on radiographic images captured using multiple overlapping DR detectors **600** as described hereinbelow. Similarly, the integrated circuit readout electronics **424** are positioned proximate a (bottom) side of the sensor array imaging device layer **402** that is opposite the x-ray source to minimize or eliminate placement of any electronic components that are not radiolucent above, or beyond an edge of, the imaging device layer **402** closest to a radiolucent edge of the DR detector **600**.

FIG. **7** illustrates in schematic form another exemplary cross-section view along section A-A of the exemplary embodiment of the DR detector **300** (FIG. **3**). Several of the components in the DR detector **700** illustrated in FIG. **7**, such as the multilayer structure, are similar in most respects to the components as described with respect to the DR detector **400** of FIG. **4** and are identified with the same

element numerals. The description of those components bearing the same element numerals is not repeated here. The DR detector **700** comprises a housing having a portion made from a radio-opaque material **714** extending along a bottom portion of the DR detector **700** and may continuously form one or two edges of the housing **714** wherein, in the perspective of FIG. **7**, one such edge may be located behind the multilayer structure as depicted therein. In separate embodiments, the radio-opaque portion of the housing **714** may continuously extend long one or two edges of the housing **712** of the DR detector **700** having four edges. If the radio-opaque portion of the housing **714** extends along two edges, it may extend along opposite edges of the DR detector **700**.

In the exemplary embodiment of FIG. **7**, a portion of the housing **712** is formed from a radiolucent material. This portion of the housing may comprise a continuous extension of the top cover **312** (FIG. **4**) to form opposite edges of the housing **712** for the DR detector **700** that are transparent to x-ray radiation. In separate embodiments, the radiolucent portion of the housing **712** may continuously extend along two, three, or all edges of a DR detector **700** having four edges. In the perspective of FIG. **7**, two opposite edges (left and right) are formed from a radiolucent material, such as a carbon fiber reinforced plastic, polymeric, or other plastic based material. The housing **712** may extend vertically between the top side and the bottom side, or it may extend at a non-orthogonal angle therebetween, as shown in FIG. **7**. In order to fasten the radiolucent portion of the housing **712**, fasteners **711**, similar in material and shape as fastener **410**, may be used in the bottom side of the DR detector to sealingly fasten the radiolucent edge of the housing **712** to the frame support **416**, or to the frame support beam **422**, as shown. The fasteners **711**, as well as integrated circuit readout electronics **424** are positioned proximate the bottom side **452**, which is a side of the sensor array imaging device layer **402** that is opposite the x-ray source to minimize or eliminate placement of any DR detector components that are not radiolucent above, or beyond an edge of, the imaging layer **402** closest to a radiolucent edge of the DR detector **600**. This helps to prevent artifacts appearing on radiographic images captured using multiple overlapping DR detectors **700** as described hereinbelow.

As described herein, DR detector embodiments **400**, **600**, and **700** are usable individually, as in standard diagnostic radiographic imaging practice, and may be combined, or tiled, as described herein, for long-length imaging. FIG. **8** illustrates a side view of an exemplary arrangement of three DR detectors including two standard DR detectors **400**, and a central DR detector **700**, as describe herein with reference to FIG. **7**, having at least two opposite edges of its housing formed from radiolucent material that each overlap one edge of one of the standard DR detectors **400**, as shown. The central DR detector **700** is positioned forward of the standard DR detectors **400** in relation to an x-ray energy source positioned to emit x-rays in a direction as depicted in FIG. **4** and FIG. **7**. The central DR detector includes an imaging array layer having one of its edges **705** overlapping an edge of the imaging array layer **307**, in a corresponding first one of the standard DR detectors **400**, by a distance **820**, and an opposite edge of the imaging array layer **707** overlapping an edge of the imaging array **305**, in a corresponding second one of the standard DR detectors **400**, by a distance **821**. The overlapping distances **820**, **821** may be equivalent or different. The overlap distance is not critical to the presently disclosed invention, and may range from one or more millimeters to tens or hundreds of millimeters. Because the

edges of the DR detector **700** that overlap the edges of the standard DR detectors **400** are radiolucent, and have eliminated or minimized components, such as electronic readout circuits, beyond the edges of the imaging layer **402** therein, a radiographic image captured simultaneously by the three detectors as depicted in FIG. **8**, will not include unnecessary artifacts in the portions of the radiographic image captured by the standard DR detectors **400** caused by radio-opaque components in the central DR detector **700** that otherwise would be disposed therein beyond the overlapping region if DR detector **700** was configured as a standard DR detector. One advantage of the embodiment depicted in FIG. **8** is that the two prior art standard detectors **400** may be used to capture a long-length image when combined as shown with only one new modified DR detector **700**. The embodiment illustrated in FIG. **8** does not require obtaining several DR detectors with modified radiolucent edges. Thus, a radiographic image simultaneously captured by the three DR detectors arranged as in FIG. **8**, may be accurately stitched together, without having to mask or process unnecessary artifacts, using standard computer implemented digital reconstruction techniques. Such known digital reconstruction methods include techniques for correcting geometric alignment of images from DR detectors having different source-to-image distance. In the example embodiment shown in FIG. **8**, a source-to-image distance of the DR detector **700** may be less than that of the DR detectors **400**.

FIG. **9** illustrates a side view of an exemplary arrangement of DR detectors including one standard central DR detector **400**, and two DR detectors **600**, as described herein with reference to FIG. **6**, each having one edge of its housing formed from radiolucent material that overlaps one edge of the standard central DR detector **400**, as shown. The central standard DR detector **400** is positioned rearward of the DR detectors **600** in relation to an x-ray energy source positioned to emit x-rays in a direction as depicted in FIG. **4** and FIG. **6**. The central standard DR detector **400** includes an imaging array layer having one of its edges **313** overlapped by an edge of the imaging array layer **607** in a corresponding first one of the DR detectors **600** by a distance **822**, and an opposite edge of the imaging array layer **311** overlapped by an edge of the imaging array layer **605** by a distance **823** in a corresponding second one of the DR detectors **600**. The overlapping distances **822**, **823** may be equivalent or different. The overlap distance is not critical to the presently disclosed invention, and may range from one or more millimeters to tens or hundreds of millimeters. Because the respective edge of each of the DR detectors **600** that overlaps the edge of the standard DR detector **400** is radiolucent, and has eliminated or minimized radio-opaque components, such as integrated electronic read out circuits, beyond the edge of the imaging layer therein, a radiographic image captured simultaneously by the three detectors as depicted in FIG. **9**, will not include unnecessary artifacts in the portion of the radiographic image as captured by the standard DR detector **400** caused by radio-opaque components in the DR detectors **600** that otherwise would be disposed therein beyond the overlapping region if DR detectors **600** were configured as standard DR detectors. One advantage of the embodiment depicted in FIG. **9** is that a prior art standard detector **400** may be used to capture a long-length image when combined as shown with two new modified DR detectors **600** each having only one edge modified to be radiolucent. The embodiment illustrated in FIG. **8** does not require obtaining several DR detectors with modified radiolucent edges. Thus, a radiographic image simultaneously captured by the three DR detectors arranged

as in FIG. **9**, may be accurately stitched together without having to mask or process unnecessary artifacts using standard computer implemented digital reconstruction techniques. Such known digital reconstruction methods include techniques for correcting geometric alignment of images from DR detectors having different source-to-image distance. In the example embodiment shown in FIG. **9**, a source-to-image distance of the DR detectors **600** may be less than that of the DR detector **400**.

FIGS. **10** and **11** illustrate top views of the DR detector arrangements as depicted in FIGS. **8** and **9**, respectively. As shown, two standard DR detectors **400** are positioned rearward of the DR detector **700** in FIG. **10**, in relation to an x-ray source that, in the perspective of FIG. **10**, emits x-ray energy into the page. The DR detector **700** includes radiolucent edges at its top and bottom edges in the Figure, which overlap the edges of the DR detectors **400**, as described in relation to FIG. **8**. In FIG. **11**, two DR detectors **600**, each as described and configured in the description of FIG. **6**, are positioned forward of the standard DR detectors **400** in FIG. **11**, in relation to an x-ray source that, in the perspective of FIG. **11**, emits x-ray energy into the page. The DR detectors **600** each include at least one radiolucent edge (top or bottom edge) which overlaps a corresponding edge of the standard DR detector **400**, as described in relation to FIG. **9**. While particular arrangements of DR detectors have been illustrated in FIGS. **8-11**, it should be noted that those skilled in the art may envisage that various combinations of DR detectors may be implemented in various geometric combinations. Thus, different types of DR detectors may be utilized in upper, central, or lower positions, or may be used in combination with four or more detectors, having edges overlapping, wherein each of the DR detectors may be configured to include one, two, three, or four radiolucent edges. Such combinations are considered to be within the scope of the present invention so long as any radio-opaque edges of a DR detector do not interfere with the x-ray beams incident upon an imaging array of another DR detector. Such radio-opaque edges may be positioned rearward of another overlapping DR detector, or may be positioned on an exterior border of the arrangement of DR detectors. Alternatively, some or all of the tiled DR detectors may be arranged in a staggered stepwise fashion (FIG. **13**), rather than having one central DR detector positioned forward or rearward of the other detectors.

FIG. **12A** illustrates a DR imaging system **1200** using the arrangement of DR detectors as described in relation to FIG. **9** and FIG. **11** for use in a long-length imaging exposure. DR detector **1201** may comprise a wired or wireless DR detector of the type **600** described in relation to FIG. **6**; DR detector **1202** may comprise a wired or wireless standard DR detector type of the type **400** described in relation to FIG. **4**; and DR detector **1203** may comprise another wired or wireless DR detector of the type **600**. X-ray source **501** may be fired once to expose a subject (not shown) to an x-ray beam **16** when the subject is placed between the x-ray radiation source **501** and the multiple DR detectors **1201-1203**, to capture a distributed image of the subject that is simultaneously captured and stored by the multiple DR detectors **1201-1203**. The captured images, each comprising a portion of the subject, one from each DR detector, may be stitched together using known computer implemented reconstruction techniques to generate a single long-length composite image of the subject. Part of the control operations carried out by the image processing and control unit **34** may include wired or wireless communication with the DR detectors **1201-1203** for verification that the DR detectors have been

initiated and are all in a ready state before exposure, for synchronization, and for coordinating storage and identification of image frame data from each of the detectors. Such a method does not require time consuming repositioning of one or more DR detectors **1201-1203**, as well as not requiring repositioning of the x-ray source **501**, or multiple exposures, as may be currently practiced to obtain a long-length radiographic image. The arrangement of DR detectors **1201-1203** may be configured by attachment to a rigid structure **1200** using a modified “bucky” arrangement to fix in position each of the DR detectors **1201-1203**, or the detectors **1201-1203** may be affixed to a wall. Alternatively, the DR detector **1202** may be part of an existing permanent radiographic imaging installation which is fixed in position as shown, while the other two DR detectors **1201, 1203**, may be portable (temporarily fixed) DR detectors. One embodiment of the present invention may comprise a retrofittable separate structure for temporarily securing in position the DR detectors **1201** and **1203** as shown and allowing movement of the structure having these two detectors **1201, 1203**, to position them in front of (overlapping) the fixed installation of DR detector **1202**, as will be described below in relation to FIG. **12B**. Although the arrangement of DR detectors **1201-1203** has been illustrated as a vertical alignment wherein the imaging planes of the DR detectors are vertical, it should be noted that any of the tiled arrangements of DR detectors disclosed herein may be positioned in a substantially horizontal alignment wherein the imaging planes of the DR detectors are horizontal, such as may be used for a human patient who is lying down on an examination bed with an x-ray source positioned above the patient, or the DR detectors disclosed herein may be positioned in a substantially horizontal alignment wherein the imaging planes of the DR detectors are vertical.

FIG. **12B** illustrates a DR imaging system **1250** using an arrangement of DR detectors as described in relation to FIG. **12A** for use in a long-length imaging exposure, except that the DR detectors **1201, 1203**, are affixed to a transport apparatus **1251** comprising a support post **1254** attached to a base **1256** outfitted with means for transporting the apparatus **1251** and DR detectors **1201, 1203**, such as wheels **1257** which may include freely rotatable wheels, lockable wheels, wheels that may be lowered or raised by hand cranking or by electric motor under operator control, wheels that are not motor-assisted, and motor driven wheels that may be powered by an electric motor to assist in manually transporting the apparatus **1251**. The support post **1254** secures in vertical relative position the DR detectors **1201, 1203** with a preselected gap size therebetween **1255** sufficient for the respective bottom and top edges of the DR detectors **1201, 1203**, to overlap a top and bottom edge of DR detector **1202**, as previously described. As mentioned above, the DR detector **1202** may represent a standard prior art DR detector permanently installed on one wall **1252** such as in a medical facility imaging room. The DR detector **1202** may be used alone with x-ray source **501** for standard non-elongated radiographic imaging and, in the case where a long-length radiographic image may be desired, the apparatus **1251** may be rolled into position **1260** along a floor of an imaging room. Similarly, DR detectors **1201, 1203**, may be usable individually for performing standard radiographic imaging of patients and may be inserted or attached to support post **1254** to configure the transport apparatus **1251** as described herein. Thus, the transportable pair of DR detectors **1201, 1203**, may be advantageously affixed to the transport apparatus **1251** to provide a capability to easily convert the permanent installation of the standard DR detec-

tor **1202** into the long-length imaging system **1250** when combined as shown with two new modified DR detectors of the type **600** each having one or more edges being radiolucent.

As before, x-ray source **501** may be fired once to expose a subject (not shown) when the subject is placed in front of the multiple DR detectors **1201-1203**. Part of the control operations carried out by the image processing and control unit **34** may include wired or wireless communications, wherein wireless communications are represented as wireless transmission signals **1258**, with the DR detectors **1201-1203**, such as waiting for and synchronizing ready state signals from all activated DR detectors **1201-1203** before an exposure by x-ray source **501**. Such a method does not require time consuming repositioning of one or more DR detectors **1201-1203**, as well as not requiring repositioning of the x-ray source **501**, or multiple exposures, as may be currently practiced to obtain a long-length radiographic image.

FIG. **13** illustrates an embodiment of a DR imaging system **1300** wherein more than three DR detectors are positioned in an overlapping fashion to capture a long-length radiographic image. X-ray source **501** may emit a single radiographic energy pulse that is received and captured by DR detectors **1301-1305** as shown. A subject positioned in front of the DR detectors **1301-1305** may result in radiographic images being generated in the DR detectors **1301-1305**, each comprising a portion of a radiographic image of the subject using the single radiographic energy pulse. As shown, DR detector **1301**, the uppermost DR detector as shown, is illustrated as a DR detector **600** as described herein with reference to FIG. **6**. Because DR detector **1301** is not positioned forward of another DR detector, it may alternatively comprise a standard DR detector such as the DR detector **400** described in relation to FIG. **4**. Moreover, DR detector **1301** may comprise a DR detector such as the DR detector **700** described in relation to FIG. **7**. Such alternate configurations are considered to be encompassed by the present disclosure because they embody preferred configurations wherein a radio-opaque edge of any DR detector used does not overlap the imaging array of another DR detector positioned behind it. In similar fashion, DR detector **1302**, second from the top as shown, may comprise a detector of the type described in relation to FIG. **7** wherein opposite edges (top and bottom edges in the perspective of FIG. **13**) are configured to be radiolucent; DR detector **1303**, third from the top as shown, may comprise a standard DR detector **400** of the type described in relation to FIG. **4**, or it may comprise a DR detector **600** or **700** as described in relation to FIG. **6** and FIG. **7**, respectively; DR detector **1304**, fourth from the top as shown, may comprise a DR detector **600** as described in relation to FIG. **6** wherein only its upper edge is configured to be radiolucent; and DR detector **1305**, at the bottom of the arrangement as shown, may similarly comprise a DR detector **600** as described in relation to FIG. **6** wherein only its upper edge is configured to be radiolucent. The detectors **1303-1305** are positioned in a staggered stepwise arrangement, which stepwise arrangement may comprise an alternative arrangement for all the DR detectors **1301-1305**, as desired. As shown, the DR detectors **1301-1305** may be fixed to a support structure **1300** for securing in position the DR detectors **1301-1305**.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, an apparatus, and a method, for capturing long length images of a subject using multiple DR detectors.

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This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A digital radiographic detector comprising:
 - a housing comprising a top side, a bottom side substantially parallel to the top side, and a plurality of edges extending between a periphery of the top side and a periphery of the bottom side to form an interior volume of the housing; and
 - a multilayer imaging structure within the interior volume of the housing, the multilayer imaging structure comprising a substantially planar imaging side configured to face the top side of the housing and to face an external radiographic energy source emitting radiographic energy toward the top side of the housing, wherein the top side of the housing comprises a radiolucent material, at least one of the plurality of edges of the housing is made from a radiolucent material, and wherein at least one of the plurality of edges of the housing is made from a radiopaque material.
2. The detector of claim 1, wherein the multilayer imaging structure further comprises:
 - an imaging device layer to receive light energy; and
 - a scintillator layer adjacent the device layer, the scintillator layer to convert the radiographic energy to the light energy.
3. The detector of claim 2, wherein the top side of the housing is sealingly attached to the at least one of the plurality of edges of the housing made from the radiopaque material.
4. The detector of claim 3, wherein the bottom side of the housing comprises a radiopaque material, the bottom side of the housing is sealingly attached to the at least one of the plurality of edges of the housing made from the radiolucent material.
5. The detector of claim 2, further comprising a scanning circuit, a read-out circuit, and a bias circuit all enclosed within the interior volume of the housing and in electrical communication with the imaging device layer.
6. The detector of claim 2, further comprising a transmitter for wirelessly communicating with an image control processing system and for wirelessly transmitting a ready signal to the image control processing system.
7. A digital radiography system comprising:
 - an x-ray source configured to emit x-rays;
 - a first DR detector comprising:
 - a housing comprising a top side, a bottom side substantially parallel to the top side, and a plurality of edges extending between a periphery of the top side and a periphery of the bottom side to form an interior volume of the housing; and
 - a multilayer structure within the interior volume of the housing, the multilayer structure comprising a substantially planar imaging side configured to face the top side of the housing and to face the x-ray source emitting the x-rays toward the top side of the housing, an imaging device layer to receive light energy,

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- and comprising a scintillator layer adjacent the device layer, the scintillator layer to convert the x-rays to the light energy,
- wherein the top side of the housing comprises a radiolucent material, and wherein two opposing parallel edges of the plurality of edges of the housing are made from a radiolucent material;
- and
- second and third DR detectors each positioned behind one of the two opposing parallel edges of the first DR detector with respect to the x-ray source and each comprising a radiopaque housing without radiolucent edges.
8. The system of claim 7, wherein the top side of the housing comprises an outermost top surface of the first DR detector.
9. The system of claim 8, wherein the top side of the housing extends continuously to form the two opposing parallel edges of the plurality of edges of the housing made from the radiolucent material.
10. The system of claim 7, further comprising an image acquisition control system configured to wirelessly communicate with the first, second, and third DR detectors and to wirelessly receive a ready signal from each of the first, second, and third DR detectors before activating the x-ray source.
11. A long-length imaging system comprising:
 - first and second DR detectors, each comprising:
 - a housing comprising a top side, a bottom side substantially parallel to the top side, and a plurality of edges extending between a periphery of the top side and a periphery of the bottom side to form an interior volume of the housing; and
 - a multilayer structure within the interior volume of the housing, the multilayer structure comprising a substantially planar imaging side configured to face the top side of the housing, an imaging device layer to receive light energy, and comprising a scintillator layer adjacent the device layer, the scintillator layer to convert radiographic energy to the light energy, wherein the top side of the housing comprises a radiolucent material, and wherein only one edge of the plurality of edges of the housing is made from a radiolucent material;
 - and
 - a third DR detector disposed behind the first and second DR detectors, such that said only one radiolucent edge of the first and second DR detectors each overlaps a different parallel edge of the third DR detector, the overlapped edges of the third DR detector comprising radiopaque edges.
12. The system of claim 11, further comprising a transportable support structure securing in a vertical relative position the first and second DR detectors with a preselected gap size therebetween.
13. The system of claim 12, wherein the transportable support structure comprises means for moving the transportable support structure such that the first and second DR detectors are simultaneously positioned forward of the third DR detector.
14. The system of claim 13, wherein the means for moving the transportable support structure comprises wheels powered by an electric motor.
15. The system according to claim 11, further comprising an x-ray source, and wherein the system is configured to capture a portion of a radiographic image of a subject on

each of the first, second, and third DR detectors simultaneously using one exposure by the x-ray source.

16. The system of claim **15**, wherein the preselected gap size is large enough for the third DR detector to be exposed by the one x-ray exposure. 5

17. The system of claim **15**, further comprising an image acquisition control system configured to wirelessly communicate with each of the first, second, and third DR detectors and to wirelessly receive a ready signal from each of the first, second, and third DR detectors before activating the 10 x-ray source.

18. The system of claim **15**, wherein the third DR detector is a non-portable DR detector fixed in a stationary position, and wherein the first and second DR detectors are each a portable independently usable DR detector. 15

19. The system of claim **11**, wherein the first, second and third detectors are disposed along a horizontal axis.

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